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LLNL-TR-673577

# Response to FESAC survey, Non-Fusion Connections to Fusion Energy Sciences: Long Duration Directional Drives for Star Formation and Photoionization

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June 19, 2015

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This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

## **Response to FESAC survey, Non-Fusion Connections to Fusion Energy Sciences: Long Duration Directional Drives for Star Formation and Photoionization**

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June 16, 2015

Category: Space and astrophysical plasmas (including laboratory astrophysics)

*(1) Briefly describe a non-fusion science or technology development in an area supported by or otherwise connected to activities of the DOE Office of Fusion Energy Sciences.*

A novel long duration (60-100 ns), directional laser-driven multi-hohlraum x-ray source is being developed to study how the famous ‘Pillars of Creation’ of the Eagle Nebula formed. Eagle Nebula was selected as one of the National Ignition Facility (NIF) Science programs, and was awarded four NIF shots to study the ‘cometary model’ of pillar formation. These experiments require a long-duration drive, 30 ns or longer, to drive deeply nonlinear ablative hydrodynamics. The new x-ray source is being used to illuminate science packages with directional radiation mimicking a cluster of stars. Astrophysical modeling by our group has shown that a ‘cometary model’ can produce Eagle-like pillar structure, and comparisons to millimeter wave observations have shown the cometary model can produce column density and velocity profiles similar to those in the Eagle Pillars. The approach is to generate a scaled pillar at NIF using the new x-ray source, and compare the velocity and density structure of the pillar with millimeter-wave column density and Doppler shift observations of Eagle and other molecular clouds performed by collaborating astronomers.

*(2) What societal benefits, including contributions to other areas of science and technology, have or are likely to result from the development described above?*

In addition to studying the formation of pillar structures, the new source can be used to study a range of other physics:

- The surface of a molecular cloud illuminated by UV radiation is a ‘photoionization’ front, in which ionization is predominantly by photons, as opposed to the collisional effects that dominate in denser plasmas. Photoionization is also of interest in the context of black hole accretion disk. Laboratory experiments to study photoionization require a long-duration drive, and scoping of the new multi-hohlraum x-ray source for this purpose has already begun.
- Star formation in molecular clouds occurs by collapse of dense gravitational condensations within the cloud, through compression by shock waves, or by radiative losses. The multi-hohlraum source and the Eagle science package are well suited to study both mechanisms.

- Exotic hydrodynamic instabilities may occur at surfaces illuminated by directional radiation. The directionality of the multi-hohlraum source can be to study these instabilities experimentally.
- Magnetic fields of a few hundred  $\mu\text{G}$  are believed to strongly influence the formation of structures in molecular clouds and the interstellar medium. A static background magnetic field can be added to the NIF Eagle experiments; the field would be compressed by material collapsing onto the pillar axis, providing pressure support that could measurably increase the observed diameter of the pillar.

Due to the iconic status of the pillars of the Eagle Nebula, this research will bring popular attention to plasma physics, HED laboratory physics, and fundamental science at NIF and other experimental facilities. The result will be to both to bring new perspectives to the studies of hydrodynamics in inertial confinement fusion and HED scenarios in general, and to promote interest in the STEM disciplines.